Modern computer programs offer an awful lot of features and extras, but these come at the price of large demands on hard disk space. Especially if your computer is already a few years old, it can be worthwhile to buy a new hard disk with more capacity than what you now have. In this article, we explain what you should look out for.

DIY hard disk installation

create lots of space — dirt cheap!

Photo: Western Digital

Operating systems and programs are becoming ever larger, and this means that they require more and more space on the hard disk. A full Windows installation can easily take up 300 to 500 MB, and let's not even talk about a full version of Microsoft Office! Fortunately, hard disk manufacturers also manage to continually increase the storage capacities of their products — you might think there is a deal between them and the software developers. On average, hard disk capacity at a given price has doubled every year for the past several years, and there seems to be no end in sight. Anyone who was proud to own a 2 MB hard disk three years ago is probably now struggling with insufficient disk capacity. Luckily, the prices of hard disks are presently quite low, so it is a good time think about buying a larger drive.

The main requirements

Let's go over the main things you should consider when buying a hard disk.

All modern hard disks are at least Ultra-DMA/33 types. The very latest models even support the Ultra-DMA/66 standard. This extended EIDE protocol provides fast data transfers between the hard disk and the motherboard. However, the motherboard must also support the protocol for it to be of any benefit. Even so, it doesn't do any harm to have it, since modern hard disks are backwards-compatible and thus will work faultlessly even with old-model IDE controllers.

Modern hard disks run at 5400 rpm or more. This is important with regard to the data transfer rate. There is an increasing number of hard disks gradually appearing on the market with significantly higher speeds, such as 7200 and even 10,000 rpm. Keep in mind that higher speeds usually mean higher noise levels. Also, high rotational speeds make little noticeable difference for normal applications.

Most hard disks have a cache (data buffer) of 256 or 512 kB. In principle, the bigger the cache the better.

The access time, which is the time required for the read/write head to move to a particular location, is an important quality factor. Commonly specified values range between 8 and 15 ms (average seek time). Be careful when comparing access time specifications between different manufacturers. One may specify 14 ms and the other 9 ms, but the latter may neglect to mention that this omits the 'latency time', which is the time required for the head assembly to settle to a stable position above the track. Latency adds around 5 ms to the seek time, and should actually be included in the average seek time specification.

In addition, as a rule the average seek time is less for 3.5" drives than for 5.25" drives. This is logical, since the heads must move farther in the larger drive.

Finally, consider how the disk will be fitted. You may need a set of mounting brackets to fit a 3.5" drive in a 5.25" mounting bay. There must also be a free power connector inside the computer housing (the large type; the small power connectors that were used several years ago are rarely found on modern hard disks). You will also need a 40-pin flat cable for connecting the disk to the motherboard. Make sure that this cable is no longer than 45 cm, since data corruption can otherwise occur, especially with Ultra-DMA drives (we're dealing with very high frequencies here).

Jumpers, jumpers, jumpers

An IDE drive always has a jumper block with (usually) 6, 8 or 10 pins, normally located next to the IDE connector. This is used to select the 'position' of the drive in the bus chain. Relatively modern motherboards always have two IDE connectors, and up to two drives can be connected to each IDE cable. The jumpers in the drive allow you to indicate whether the drive is the only one connected to the cable, or whether it is the first (master) or second (slave) drive if two

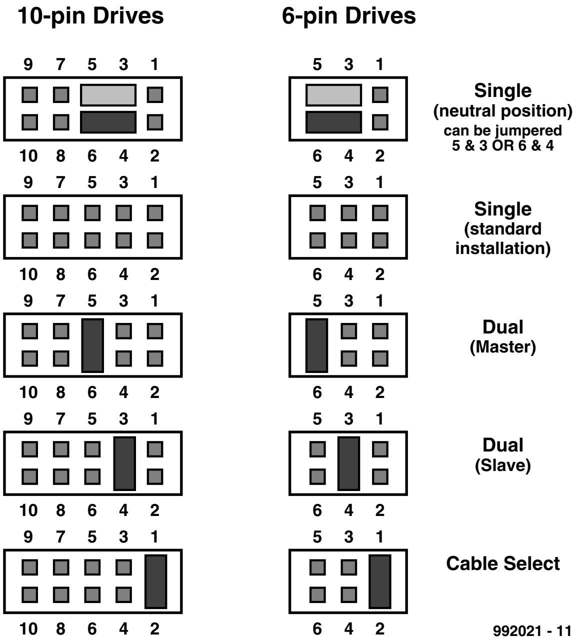
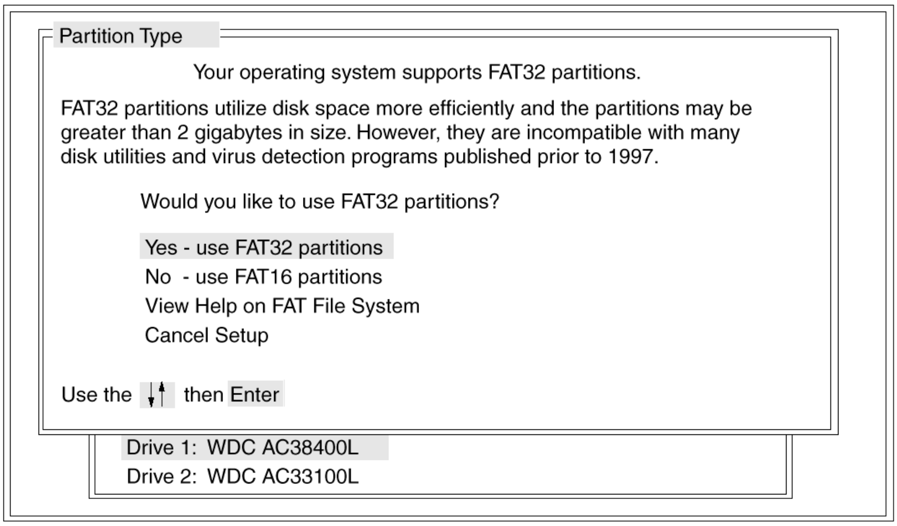


Figure 1. A hard disk can be set up as a solitary disk, a master or a slave by means of a few jumpers. This example shows the jumper settings for modern Western Digital drives.



Partition Type

Your operating system supports FAT32 partitions.

FAT32 partitions utilize disk space more efficiently and the partitions may be greater than 2 gigabytes in size. However, they are incompatible with many disk utilities and virus detection programs published prior to 1997.

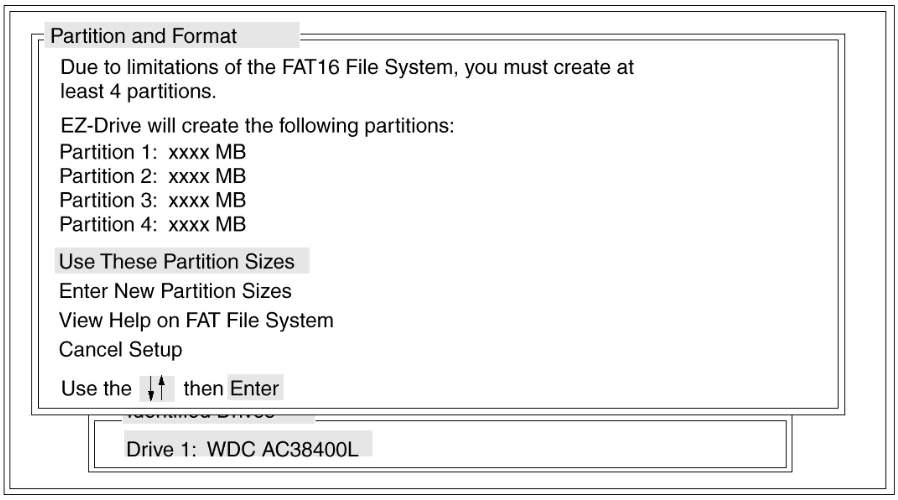
Would you like to use FAT32 partitions?

Yes - use FAT32 partitions
No - use FAT16 partitions
View Help on FAT File System
Cancel Setup

Use the ↓↑ then Enter

Drive 1: WDC AC38400L
Drive 2: WDC AC33100L

Figure 2. A disk manager, such as EZ-Drive, allows the full disk capacity to be used with an old version of the BIOS.



Partition and Format

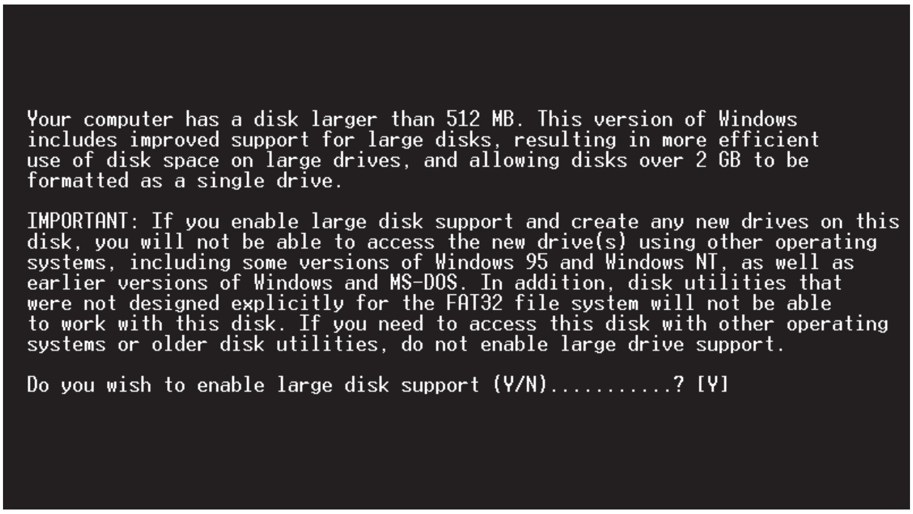
Due to limitations of the FAT16 File System, you must create at least 4 partitions.

EZ-Drive will create the following partitions:
Partition 1: xxxx MB
Partition 2: xxxx MB
Partition 3: xxxx MB
Partition 4: xxxx MB

Use These Partition Sizes
Enter New Partition Sizes
View Help on FAT File System
Cancel Setup

Use the ↓↑ then Enter

Drive 1: WDC AC38400L

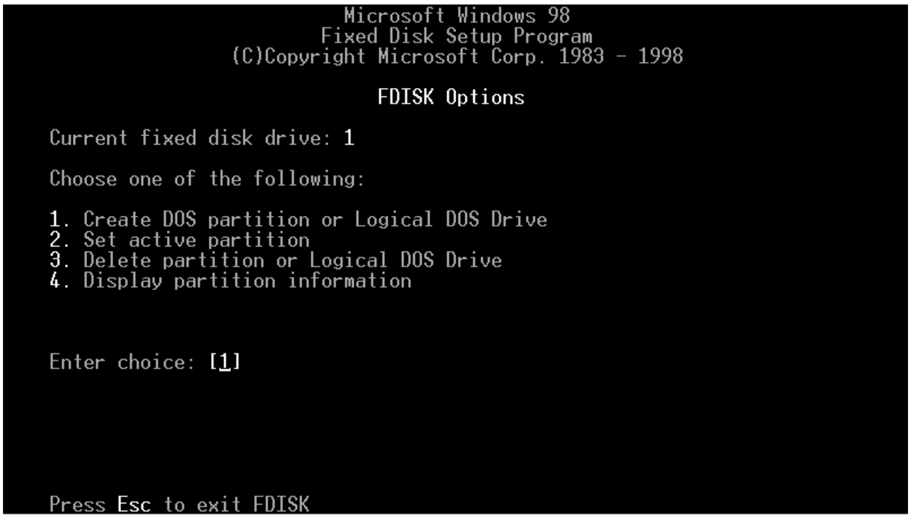


```
Your computer has a disk larger than 512 MB. This version of Windows
includes improved support for large disks, resulting in more efficient
use of disk space on large drives, and allowing disks over 2 GB to be
formatted as a single drive.

IMPORTANT: If you enable large disk support and create any new drives on this
disk, you will not be able to access the new drive(s) using other operating
systems, including some versions of Windows 95 and Windows NT, as well as
earlier versions of Windows and MS-DOS. In addition, disk utilities that
were not designed explicitly for the FAT32 file system will not be able
to work with this disk. If you need to access this disk with other operating
systems or older disk utilities, do not enable large drive support.

Do you wish to enable large disk support (Y/N)...........? [Y]
```

Figure 3. With the latest versions of Windows, you can select FAT32. After this you can divide the hard disk into primary and secondary partitions.



```
                         Microsoft Windows 98
                        Fixed Disk Setup Program
                (C)Copyright Microsoft Corp. 1983 - 1998

                             FDISK Options

   Current fixed disk drive: 1

   Choose one of the following:

   1. Create DOS partition or Logical DOS Drive
   2. Set active partition
   3. Delete partition or Logical DOS Drive
   4. Display partition information


   Enter choice: [1]




   Press Esc to exit FDISK
```

drives are connected.

The jumper settings are usually marked on the drive. If this is not the case, you should be able to quickly determine what they are from the vendor or the manufacturer's Internet site. Almost all manufacturers use three standard configurations: single (one drive only), master and slave (two drives). In addition, there is almost always a cable-select setting, but this is not needed for normal use. **Figure 1** shows an example of the jumper settings for modern Western Digital drives.

By the way, it is not always possible to use a fairly old drive (more than five years old) in combination with a new, modern drive. They may not cooperate with each other. You just have to try it and see whether it works.

BIOS settings

After you have fitted the new hard drive, you must enter the proper BIOS settings before it will be recognized by the rest of the hardware. Relatively modern motherboards have an intelligent BIOS that reads out the drive parameters for itself and then makes all the correct settings. In addition, there is often a BIOS menu item called 'IDE HDD auto detection'. If you select this, the computer searches through all devices connected to the IDE interface and requests their configuration data. It also checks for a number of mode options, such as PIO and LBA. You can select a particular configuration, which is then stored in the CMOS RAM on the motherboard. With an older-model BIOS, you will have to manually enter the necessary parameters in the CMOS setup (number of cylinders, heads and sectors). This information is normally printed on the hard disk drive. The 'precomp' setting is no longer used, so you can leave it at zero, and you should set the landing zone equal to the highest cylinder number or even more.

Don't forget to enable LBA (logical block addressing) in the BIOS if the hard disk is larger than 528 MB. Otherwise it's not possible to use the full capacity of the disk. However, this only applies to operating systems that work with FAT16 or FAT32 disk formats. In addition, none of this information about the BIOS settings applies to SCSI drives, which are installed via the BIOS of the SCSI controller.

There's one final trick that you should know about if you have used a particular disk in the past with a disk manager or boot manager, and now want to use it in a more recent computer. Frequently, this causes problems due to a conflict between the (hidden) utility program in the boot sector and the new BIOS or operating system. You can 'clean up' the boot sector of the hard disk by simply entering the command

```
FDISK/MBR
```

This will not cause any data loss on the hard disk.

Capacity limits

A hard disk is divided up into a number of cylinders, heads and sectors. This is a set of 'working parameters' that is passed on to the BIOS, but it usually does not represent the actual physical configuration of the hard disk. If we multiply the values of all three parameters together, we have the capacity of the hard disk. Before 1995, computers could only work with hard disks smaller than 528 MB (the maximum numbers were 1024 cylinders, 16 heads and 64 sectors). After that, the limits were extended to 2.1 GB (4096 cylinders). More recent motherboards can handle capacities up to 8.4 GB with no problems, and the very latest models have a theoretical limit of around 124 GB!

There is no general rule for determining the maximum disk capacity that a given motherboard can handle. Usually it is necessary to delve into the CMOS setup of the motherboard and see what the maximum values are that can be entered. It may be necessary to update the BIOS to provide support for large-capacity disks.

Another possibility for an older-model motherboard is to use a disk manager, which is a special program that works around the limitations of the motherboard. The disk manager stores a small program in the boot sector of the hard disk, and this program runs every time the computer is started up. It uses clever tricks to avoid the disk capacity limitations of the motherboard.

If you buy a 'retail' version of a hard disk, you will probably find that a disk manager program (such as EZ-Drive or Disk Manager) is included (see **Figure 2**). If you need a disk manager, you can always download one for free from the Internet site of the disk manufacturer (among others, EZ-Drive is available from the Western Digital site and Disk manager from the Seagate site).

Partitioning

Although a brand new hard disk already has a basic storage structure, this is not enough to allow it to be used by the operating system. It is first necessary to divide the available capacity into one or more (active) partitions, and then to format each of the partitions to produce clusters of a particular size.

Partitioning is the process of splitting a hard disk into one or more 'logical' drives, each of which can be assigned its own drive letter. With DOS and Windows, a primary DOS partition is essential, and you may also have an extended DOS partition. An extended partition can be subsequently divided into a number of logical drives (stations).

For DOS and Windows, the program Fdisk is used to divide a hard disk into a number of partitions. It is a good idea to make a boot diskette containing the Fdisk and Format programs (among others), and preferably also the drivers needed to activate a CD-ROM drive, before you start to partition a hard disk. Make sure that you use the versions of these programs that came with the most recent version of Windows that you have.

If we take a modern Windows version as an example (Windows 95 OSR2 or Windows 98), the first thing that Fdisk asks after it starts is whether you want to enable support for large disks (see **Figure 3**). This means that you can choose here between a FAT16 system and a FAT32 system (FAT means 'file allocation table', which is a sort of library that keeps track of what programs are stored where on the hard disk). FAT32 is the system that supports large disks, and if you chose this then larger partitions and smaller clusters will be supported on the hard disk (we'll come back to this later).

It is best to select large-disk support, but you should be aware that FAT32 can only be used under Windows 95 OSR2 and Windows 98. A FAT16 partition is required for old-fashioned DOS programs that will not run in a Windows window.

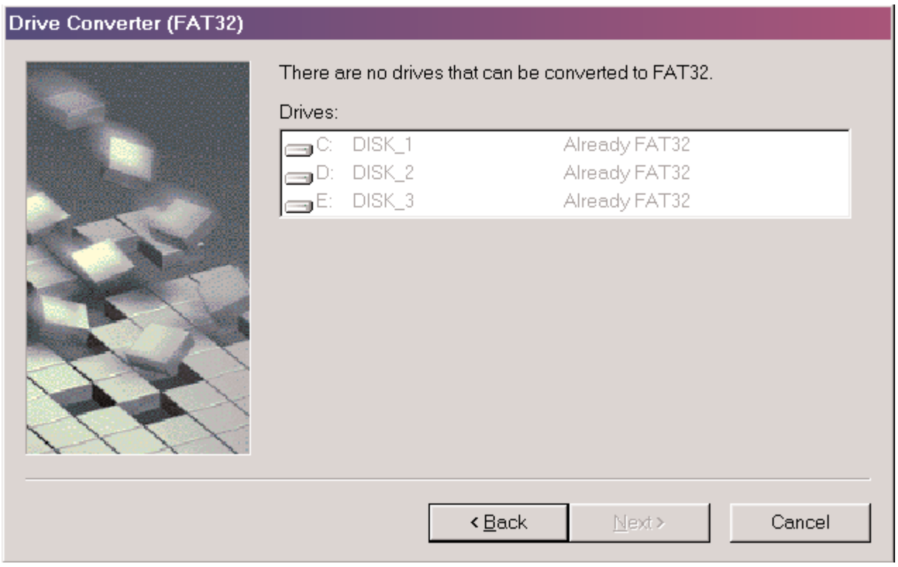
If you use Windows 98, you can initially select FAT16 and later convert one or more partitions to FAT32 with the help of the program Drive Converter (DRV1.EXE), to be found on the Windows 98 CD-ROM (see **Figure 4**). If you do this, there's no way back — a FAT32 partition cannot be changed back to FAT16! However, a combination of FAT16/FAT32 is possible on a single hard disk by starting FDISK a few times with a different FAT selection.

One or two hard disks?

Normally, a DOS-based operating system assigns the drive letter A to the first physical floppy drive that it finds in the system. If there is a second floppy drive, it is assigned the letter B; otherwise B is not assigned.

The system always assigns drive letter C to the primary DOS partition of the first physical hard disk drive. After this, the system looks for a second hard disk. If it finds a second hard disk, it checks to see if it contains a primary DOS partition. If it does, then this partition receives the drive letter D.

If the system does not find any other

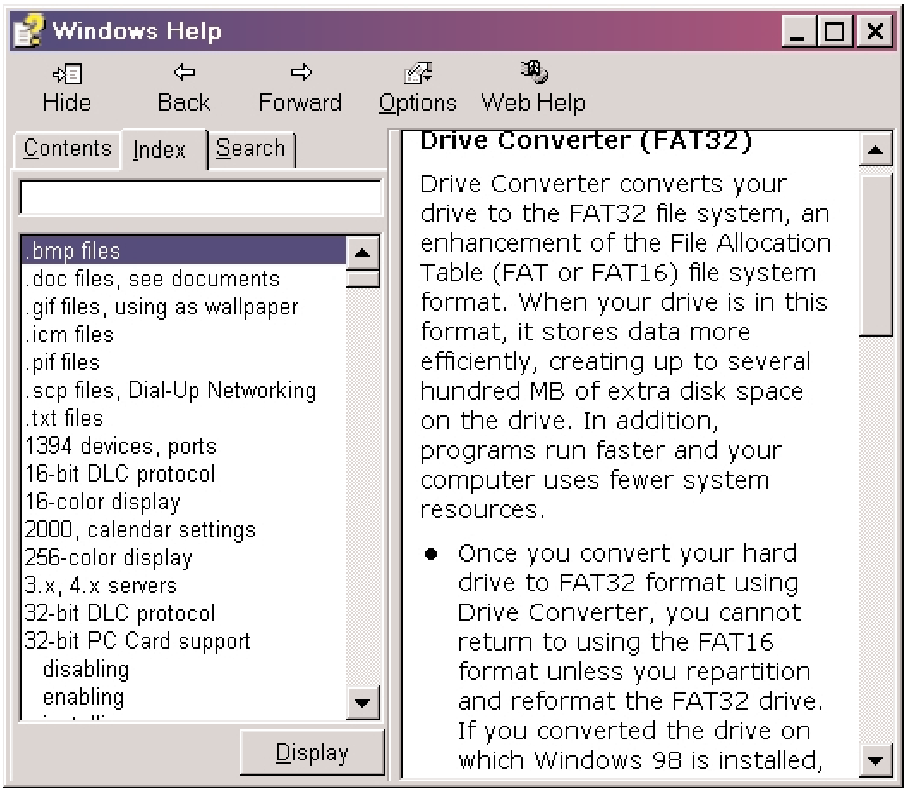


There are no drives that can be converted to FAT32.

Drives:

C: DISK_1 Already FAT32
D: DISK_2 Already FAT32
E: DISK_3 Already FAT32

Figure 4. The Drive Converter utility that comes with Windows 98 can be used to convert a FAT16 partition to FAT32.



.bmp files
.doc files, see documents
.gif files, using as wallpaper
.icm files
.pif files
.scp files, Dial-Up Networking
.txt files
1394 devices, ports
16-bit DLC protocol
16-color display
2000, calendar settings
256-color display
3.x, 4.x servers
32-bit DLC protocol
32-bit PC Card support
  disabling
  enabling

Drive Converter (FAT32)

Drive Converter converts your drive to the FAT32 file system, an enhancement of the File Allocation Table (FAT or FAT16) file system format. When your drive is in this format, it stores data more efficiently, creating up to several hundred MB of extra disk space on the drive. In addition, programs run faster and your computer uses fewer system resources.

- Once you convert your hard drive to FAT32 format using Drive Converter, you cannot return to using the FAT16 format unless you repartition and reformat the FAT32 drive. If you converted the drive on which Windows 98 is installed,

Table 1. Hard disk data transfer rates.

IDE-bus

IDE (ATA):	
single word DMA 0	2.1 MB/s
PIO mode 0	3.3 MB/s
single word DMA1, multi word DMA 0	4.2 MB/s
PIO mode 1	5.2 MB/s
PIO mode 2, single word DMA 2	8.3 MB/s
EIDI (ATA-2):	
PIO mode 3	11.1 MB/s
multi-word DMA1	13.3 MB/s
PIO mode 4, multi-word DMA 2	16.6 MB/s
Ultra-ATA (Ultra-DMA/33):	
multi-word DMA 3	33.3 MB/s

For comparison, a few transfer rates for SCSI hard disks:

SCSI-bus

	8-bit SCSI (50-lead cable)	16-bit SCSI (68-lead cable)
SCSI1	5 MB/s	-
Fast SCSI, SCSI II	10 MB/s	20 MB/s
Fast-20, Ultra SCSI	20 MB/s	40 MB/s
Fast-40, Ultra-2 SCSI	40 MB/s	80 MB/s

hard disks (a total of eight are allowed), it returns to the first hard disk and looks to see if it contains any logical drives (in an extended partition). It assigns sequential drive letters to any such logical drives. After this, it checks the second hard disk and assigns sequential drive letters to any logical drives it finds there.

In principle, all partitions have now been assigned drive letters. However, to maintain compatibility with old versions of DOS, the system next checks to see if there are any other primary DOS partitions on any of the drives. This was namely possible with some of the older versions of DOS. If any such partitions are present, the system assigns drive numbers to them as well. Virtual devices, such as CD-ROM drives and Zip drives, now get their turn. However, device drivers must usually be loaded for such devices before drive numbers can be assigned to them.

Table 2. Standard cluster sizes for various partition sizes.

FAT16

Partition size	Cluster size
< 32 MB	512 KB
< 64 MB	1 KB
< 128 MB	2 KB
< 256 MB	4 KB
< 512 MB	8 KB
< 1 GB	16 KB
< 2 GB	32 KB

FAT 32

Partition size	Cluster size
< 512 MB	not possible (FAT16)
< 8 GB	4 KB
< 16 GB	8 KB
< 32 GB	16 KB
> 32 GB	32 KB

If there is only one hard disk in the system, then the situation is usually clear. In this case you create a primary DOS partition plus an extended DOS partition, and you divide the extended partition into several logical drives. These are assigned the drive letters C, D, E … in sequence.

With two hard disks, it's more complicated. You have to be especially careful if you want to use continue to use the old hard disk as a second drive and you want to partially copy its contents to the new hard disk.

There are two possibilities in this case. The first, and least confusing, is to completely repartition both drives if you plan to use the new drive as the first drive (which is to be recommended, since is will usually be faster than the old one). You then have something like the following:

Partitions:
Hard disk 1
drive C: (primary DOS partition)
drive D: (logical drive 1 in extended DOS partition)
drive E: (logical drive 2 in extended DOS partition)
Hard disk 2
drive F: (logical drive 1 in extended DOS partition)
drive G: (logical drive 2 in extended DOS partition)
drive H: (logical drive 3 in extended DOS partition)

As you can see, hard disk 1 has a primary DOS partition and an extended DOS partition, but the second hard disk has only an extended partition. This causes all partitions to be nicely assigned drive letters in sequence.

Suppose that instead of this, you want to use your old disk as the second disk as it is, without altering the way it is partitioned. You will in any case have to make a primary partition on the new hard disk, plus an extended partition if you wish, since otherwise the system cannot boot from the hard disk. If both the old disk and the new disk have three partitions, you end up with the following arrangement:

Hard disk 1
drive C: (primary DOS partition)
drive E: (logical drive 1 in extended DOS partition)
drive F: (logical drive 2 in extended DOS partition)
Hard disk 2
drive D: (primary DOS partition)
drive G: (logical drive 1 in extended DOS partition)
drive H: (logical drive 2 in extended DOS partition)

Naturally, you can learn to live with this, but you always have to take the 'non-sequential' assignment of drive letters into account. For instance, if you want to copy a file from the old drive C to the new disk, you have to do this by copying it from drive D to (for example) drive E.

The limitations of FAT16

With Windows 95 and the first versions of Windows 98, the maximum addressable partition size was 2.1 GB (due to FAT16 and a maximum cluster size of 32 kB). This means that users of these systems must always divide hard disks with more than 2.1 GB capacity into partitions that are smaller than 2.1 GB. This restriction was removed by FAT32 in the second service release of Windows 95.

Formatting

After the hard disk has been divided into partitions, the operating system can assign and recognize drive letters, but the disk is still not ready for use. First the partitions must be formatted, which amounts to organizing them into ‘bite-sized’ chunks that the FAT can work with. The familiar Format command, used for formatting floppies under DOS, is also used for formatting the hard disk. The command

```
format c: /s
```

causes drive C (or better, partition C) to be formatted, following which the system files of the operating system are immediately copied drive C so that it can subsequently be used as the start-up disk. The suffix /s is naturally not needed for formatting the other partitions.

Large and small clusters

When a drive is formatted, it is divided up into clusters. A cluster is not the same thing as a sector, which is the smallest physical data structure on the hard disk (512 bytes). A cluster consists of several sectors. Each cluster has an entry in the FAT, from which it can be assigned to a file. Given that the FAT has a maximum size, and considering that looking up clusters in the FAT becomes slow if the FAT is too large, the cluster size varies with the size of the partition. If only for this reason, it is advisable to divide a large hard disk into two or three partitions (such as three 2 GB partitions for a 6 GB hard disk). FAT16 is not only limited to a maximum drive capacity of 2.1 GB, it also supports a much smaller number of clusters than FAT32 (which is hinted at by the number ‘16’). Table 2 shows the cluster sizes for various partition sizes with FAT16 and FAT32. It is a good idea to choose a compromise between the cluster size and the total number of clusters. This will avoid wasting too much disk space on the one hand, and having a large FAT that degrades system performance on the other hand. As a simple example, if FAT16 is used with a partition size of 2 GB, the cluster size is 32 kB. If a 1 kB icon file is written to the disk, it thus takes up 32 kB. This can lead to a lot of wasted space, especially if a lot of very small files are stored, so that only 1 to 1.5 GB of the original 2 GB is effectively being used. Fortunately, the situation is better with FAT32, but you should be careful not to let the total number of clusters become so large that it slows down the computer. For example, with a partition size of 2 GB and a cluster size of 4 kB, we already have half a million cluster allocations!

It is advisable to manually increase the cluster size for partitions from 2 to 8 MB. This can be done with the undocumented format option /z:x, where x is the number of 512-byte sectors that should make up a cluster. For instance, the command

```
format /z:16
```

will divide the hard drive into clusters of 8 kB (16 ⇔ 512 bytes).

Conclusion

Keep in mind that ‘low-level’ operations on a hard disk are almost always destructive, which means that they erase all data on the disk. Before you start, be sure to make a backup of any data on the hard disk that you want to keep. If you want to alter partitions without losing the data already present, you can use a commercial program such as Partition Magic. Unfortunately, these programs are not inexpensive, and it’s a shame to lay out so much money for something that you use only a few times.

(992021)